Experiments with Piezo Ceramics (2)

applications of ceramics in electronics

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Piezo ceramics are everywhere. Manufacturers have produced special ceramics optimised for different applications: one example is the thin disc-shaped piezo sound transducer used in the experiments described here.

How do piezo transducers manage to make such a loud noise when the movement they make is so small? Here is the trick: the ceramic is always bonded to a thin sheet of metal. The ceramic disc stretches while the metal does not, and so a relatively large bending motion is produced (**Figure 1**). Also, the stiffness and mass of the materials are chosen so as to produce a resonance at a frequency of a few kilohertz.

Since ordinary piezo transducers (**Figure 2**) operate on the same principle as we have already explored in capacitors, we ought to be able to repeat all the experiments we described using the capacitor, and get much better results.

The transducer can be charged and then warmed with a finger. Connect a pair of headphones and you will hear a loud crackling noise. On cooling you can again hear the crackling, and again when warmed again — and so on. The experiment will now work with a pair of low-impedance (for example 32 Ohm) headphones.

A loudspeaker — and more

Using the piezo transducer as a loudspeaker is simple. If an audio frequency signal is connected, it is found that only a few millivolts are required to get an audible sound. If the diaphragm is made bigger (for example by attaching a piece of card), the sound is made louder. If you are near to a medium wave transmitter you can make a simple crystal set

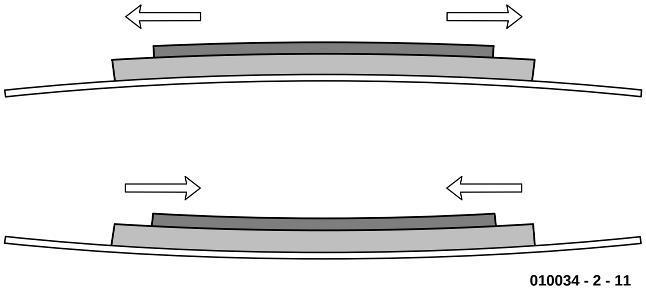


Figure 1. Principle of the ceramic transducer.

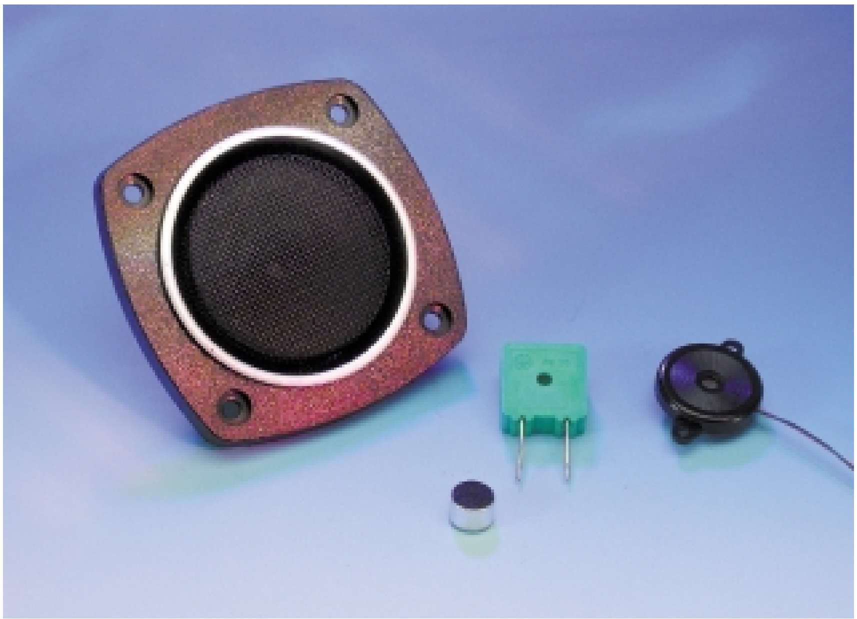


Figure 2. Practical implementation of the ceramic transducer.

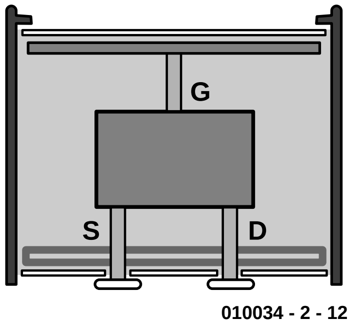


Figure 3. Construction of an electret condenser microphone.

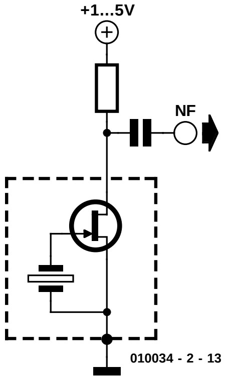


Figure 4. Connection to an external supply.

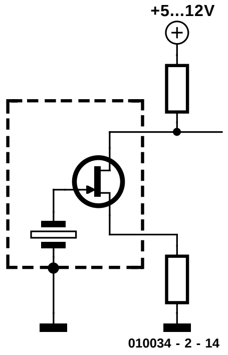


Figure 5. Connections to a passive infrared sensor.

using a piezo transducer for a loudspeaker.

As soon as the slice of ceramic is heated above the Curie temperature it loses its polarisation. It is necessary to be very careful when soldering it, to ensure that at worst only a small area is affected. If you are determined to destroy your piezo transducer, simply dip it in hot water: the transducer will no longer work.

The transducer can be repolarised be applying 300 V while warming it. It will work again, but not as well as before: in manufacture a much higher voltage is used.

Piezo ceramics are widely used in acoustic transducers, but they have very lots of other applications, including:

- Piezo ceramic igniters in cigarette lighters or gas lighters generate up to 10 kV.
- In glass delay lines tiny ceramic elements are used as piezo-acoustic transducers.
- Ceramic filters convert electrical impulses into mechanical ones, and vice versa.
- In video recorders ceramic elements are used for fine alignment of the head with the track on the tape.
- Ultrasound microphones use resonant piezo ceramics.

In principle, any piezo transducer can also be used as a microphone. They are used, for example, in recording sounds produced by equipment or objects. For normal use, however, the sharp resonance and low bandwidth make them unsuitable.

Electret and PIR

We are all familiar with electret condenser microphones with their particularly high sensitivity and frequency range. Here, a very thin sheet of polarised plastic is used, which forms one side of a charged capacitor. An integrated FET provides the required amplification (**Figure 3** and **Figure 4**).

The construction of passive infrared (PIR) sensors, as used in motion detectors, is very similar. A sliver of a suitable crystal (for example, lithium tantalate) is warmed by the incident infrared radiation and the voltage across it changes. Here too a FET is used as a preamplifier, and we have three connections, since both source and drain of the FET are brought out to pins (**Figure 5**).

If a microphone and a passive infrared sensor are so similar, it seems reasonable to suppose that they could be interchanged. The infrared sensor has a thick case and an optical filter, which will surely block out sound, so we must first open the case before we test its suitability as a microphone. The other way round, things are simpler. A simple ohmmeter suffices to determine whether an electret microphone makes a good heat sensor, and indeed a response to change in temperature can be detected. The effect, however, is only small, and so there is no danger of the weather affecting any audio recordings!

The experiments we have looked at so far have shown that there is a close relationship between ceramic capacitors, piezo transducers, condenser microphones and passive infrared sensors. Now a few typical applications will be described. Only piezo transducers and polarised ceramic capacitors will be employed. In general piezo transducers have a capacitance of around 50 nF and for many uses are much more sensitive than ordinary capacitors.

Measurement amplifier

A measurement amplifier for slowly-varying signals must have a long time constant. Here we are working with a 100 nF capacitor, and so we shall require a high input resistance. For a time constant of a few seconds we require an input resistor of around 10 MΩ. If we do away with the resistor and use an amplifier with a FET input, then the input voltage will vary uncontrollably. Resistors with values of many MΩ are not so common, and so instead we simply use a diode. When conducting, a diode is essentially an adjustable resistor with a very wide adjustment range. As the diode current is reduced, so the resistance increases.

Figure 6 shows the circuit of the amplifier. A type LM358 operational amplifier is run from a single power supply. It has PNP input stages and requires an input current of around 50 nA, which here flows through a type 1N4148 silicon diode. At this current the voltage across the diode is about 0.1 V, and so the DC resistance is about 2 MΩ. The differential input impedance is lower, however, at about 1MΩ. Thus, with a transducer with a capacitance of 50 nF, we obtain a time constant of around 50 ms. This means that the output voltage will be more affected by the rate of temperature change than by the temperature itself: almost exactly the behaviour of a PIR sensor.

The gain of the circuit is 28. The quiescent voltage at the output is about 3 V, and variations are observed around this average value.

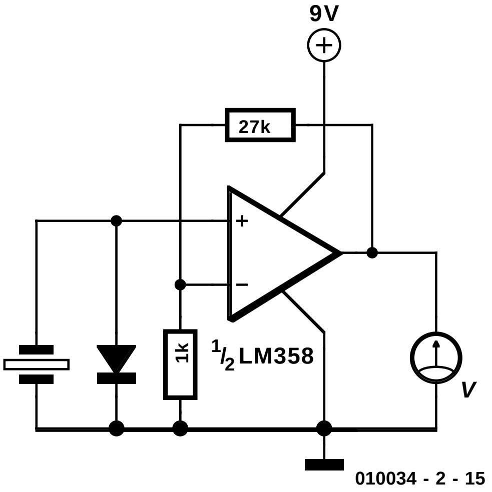
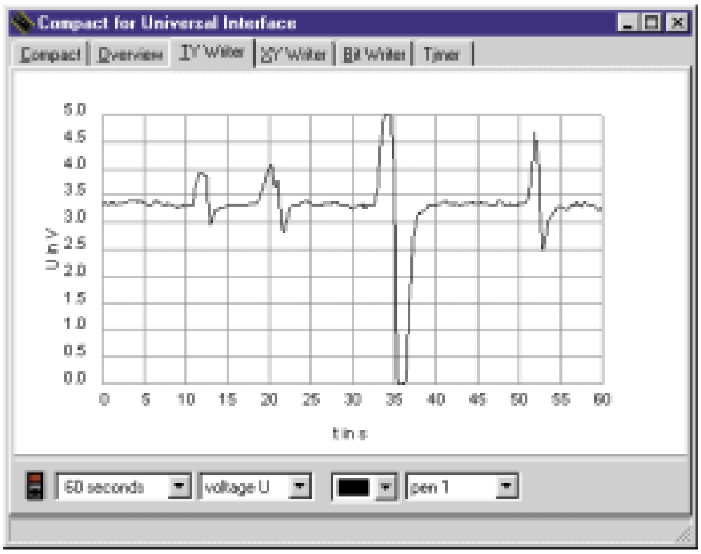


Figure 6. Sensor amplifier for temperature changes.


Compact for Universal Interface

60 seconds
voltage U
pen 1

Figure 7. Temperature change readings on a PC.

These variations can be plotted using, for example, the ‘Universal Interface for Windows’ published in the December 1999 PC Topics Supplement of *Elektor Electronics*, along with its control software. **Figure 7** shows how the sensor responds to an approaching hand: the heat from the hand produces a clear signal.

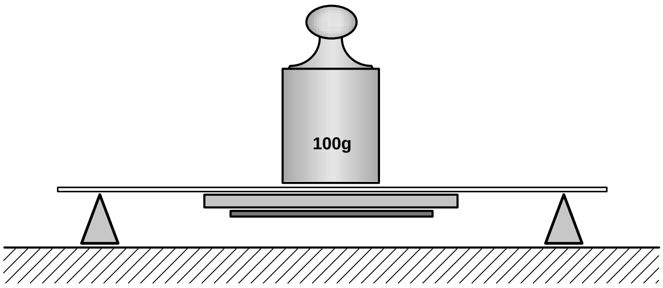


Figure 8. Use of a piezo transducer as a vibration sensor.

Vibration sensor

A piezo transducer can be used as a vibration sensor. With the use of a suitable weight (say up to 100 g) it can be used to record vibrations in the ground, which are almost always present for one reason or another (**Figure 8**). Here we are interested in signals in the middle frequency range, but our amplifier has no lower cutoff frequency. By adding a capacitor to the negative feedback path as shown in **Figure 9** we can provide such a cutoff. Now we can set a desired centre voltage using a voltage divider. Using a TLC272 the circuit can be run from a single 5 V power supply.

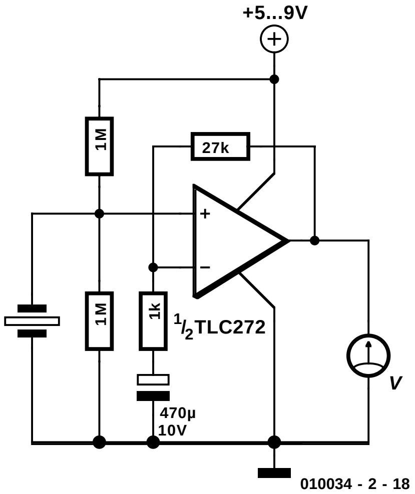


Figure 9. A measurement amplifier for the vibration sensor.

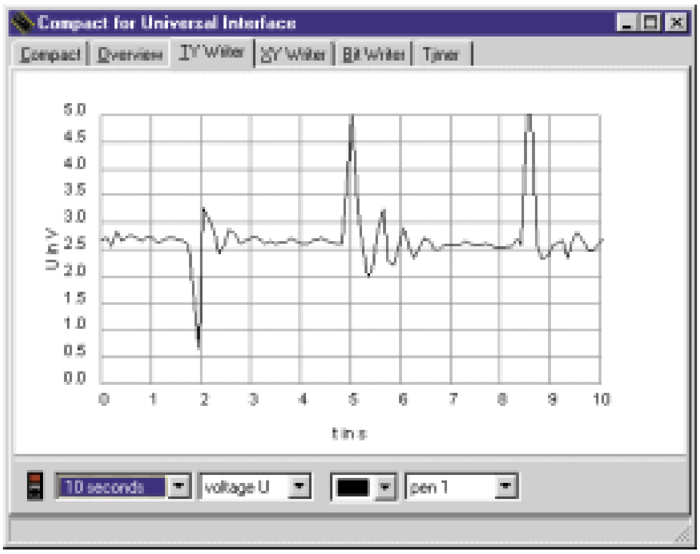
Figure 10 shows the vibration of a tabletop lightly tapped by a finger. We have here the makings of a sensitive earthquake detector. A normal piezo transducer can serve as sensor; if we use polarised capacitors we can use rather greater weights.

Ceramic scales

The arrangement for the force sensor is similar to that for the vibration sensor. A pan and some kind of fixing to the sensor are required, and both should, if possible, be made of a material with a low thermal conductivity (**Figure 11**). With this balance temperature sensitivity is a problem, since the sensor reacts to changes in both temperature and force. Poor construction can mean that the measurement results are affected by whether the item being weighed is hot or cold.

The amplifier must have a very high input impedance. A TLC272 CMOS operational amplifier fits the bill. In addition we need an input filter to block high frequency signals. In the circuit of **Figure 12** the charge produced is divided between the sensor and the 100 nF filter capacitor. The signal amplitude is therefore only about one third of what it would be without the filter, but this can be compensated for by adjusting the gain of the amplifier: we can in practice set any scale factor we want.

Figure 13 shows some measurements taken with our home-made balance on a time chart. Three dif-



10 seconds | voltage U | pen 1

Figure 10. Measuring the vibration of a tabletop.

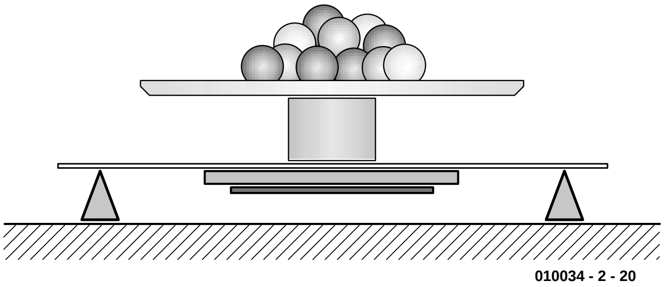
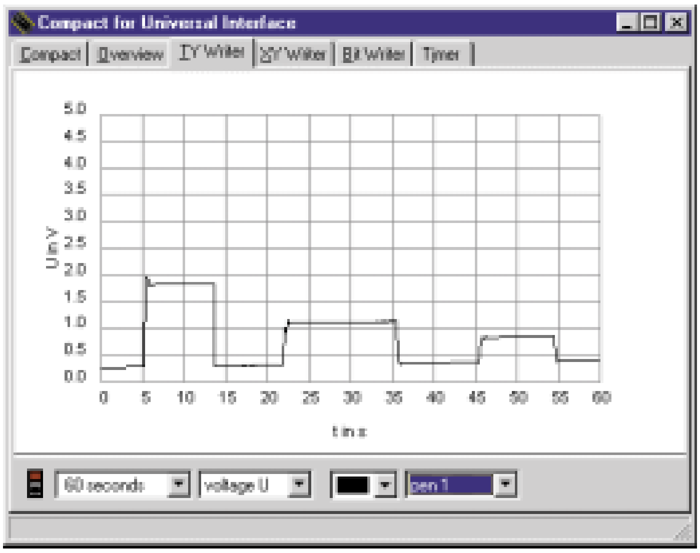


Figure 11. Experimental construction of an electric balance.



60 seconds | voltage U | pen 1

Figure 13. Static measurements with an electric balance.

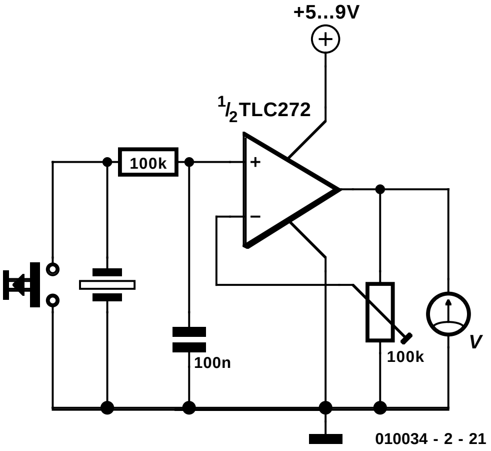


Figure 12. A measurement amplifier with a high input impedance.

ferent masses were placed on the balance and then removed. As can be seen, the measurement is basically static, but there is a discernible continuous slow rise in the offset voltage. This might be attributed to a temperature change or a leakage current in the operational amplifier. Nonetheless the balance is usable, as long as we adjust the offset voltage before each measurement. The circuit is provided with a discharge pushbutton for this purpose.

This arrangement of a piezo sensor as a balance is naturally rather experimental, and we cannot expect to achieve great accuracy. However, we can for example build a simple pair of postal scales with very little effort. The piezo transducer is suitable for masses up to around 100 g; with polarised capacitors we can weigh rather greater masses, up to several kilograms. One can imagine, for example, an arrangement where three tubular capacitors support a surface bearing the load to be weighed.

Once one has begun to try so many experiments, the possibilities start to seem endless. It is interesting, for example, to consider using a transducer in a liquid. Using a waterproof watch it has been observed that the alarm signal can be heard from one end of a swimming pool to the other, a distance of 25 m. Hence the energy transfer from the transducer into the liquid is efficient. And so we are immediately led to many new applications: what about an echo sounder? Or an ultrasound cleaning device? Or how about eavesdropping on your goldfish?

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